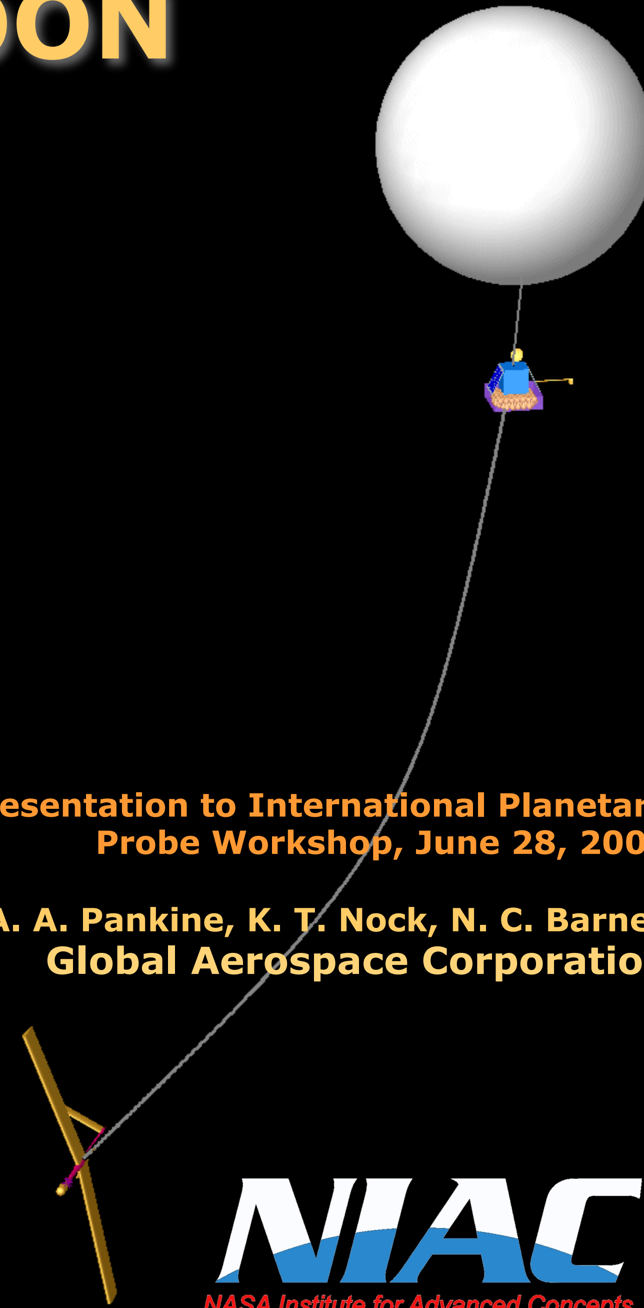
GUIDED MARS BALLOON PLATFORMS



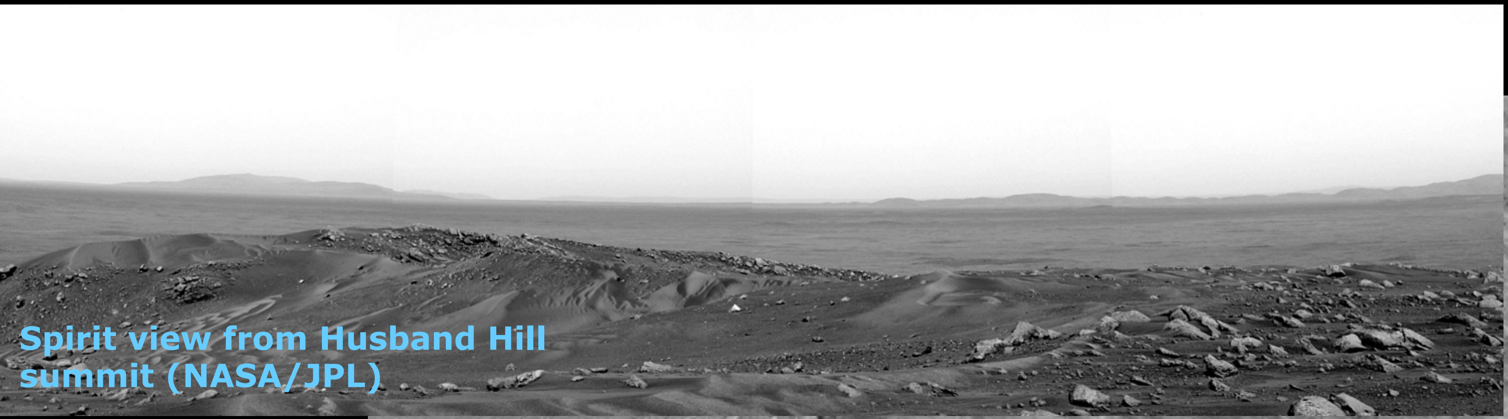
Presentation to International Planetary Probe Workshop, June 28, 2006

A. A. Pankine, K. T. Nock, N. C. Barnes
Global Aerospace Corporation

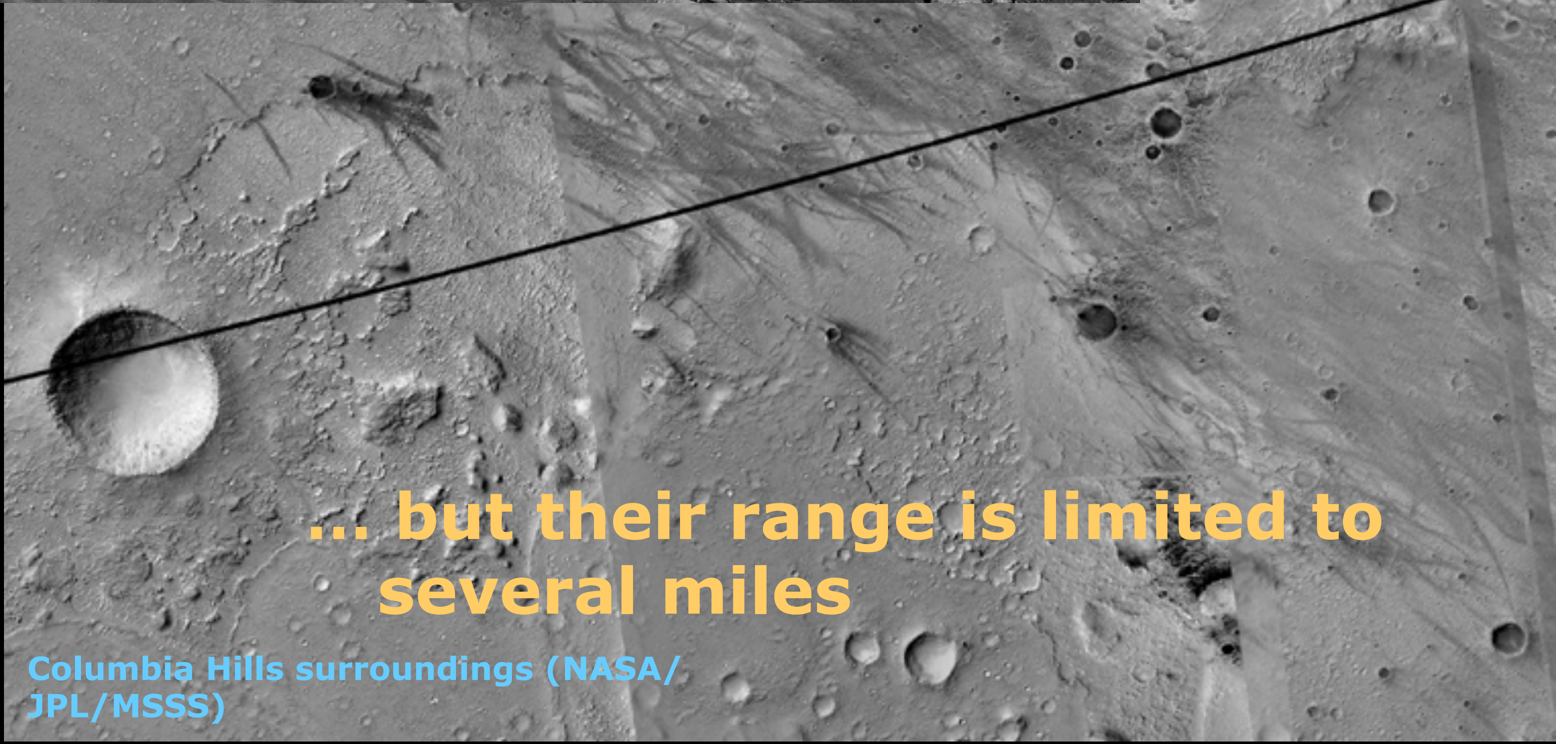
Global Aerospace Corporation

NIAC
NASA Institute for Advanced Concepts

MARS ROVERS ARE A GREAT SUCCESS...



Spirit view from Husband Hill summit (NASA/JPL)



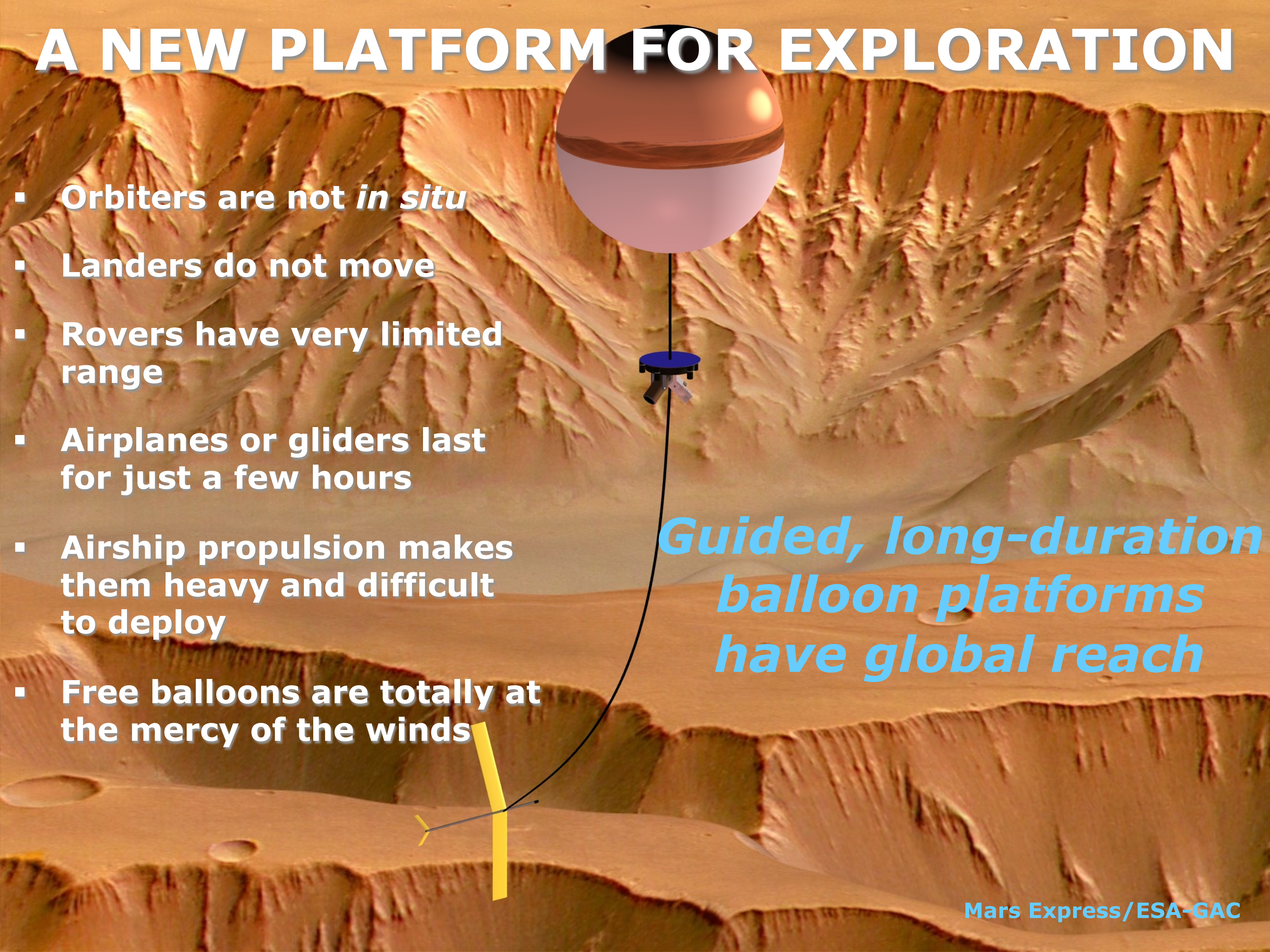
... but their range is limited to several miles

Columbia Hills surroundings (NASA/JPL/MSSS)

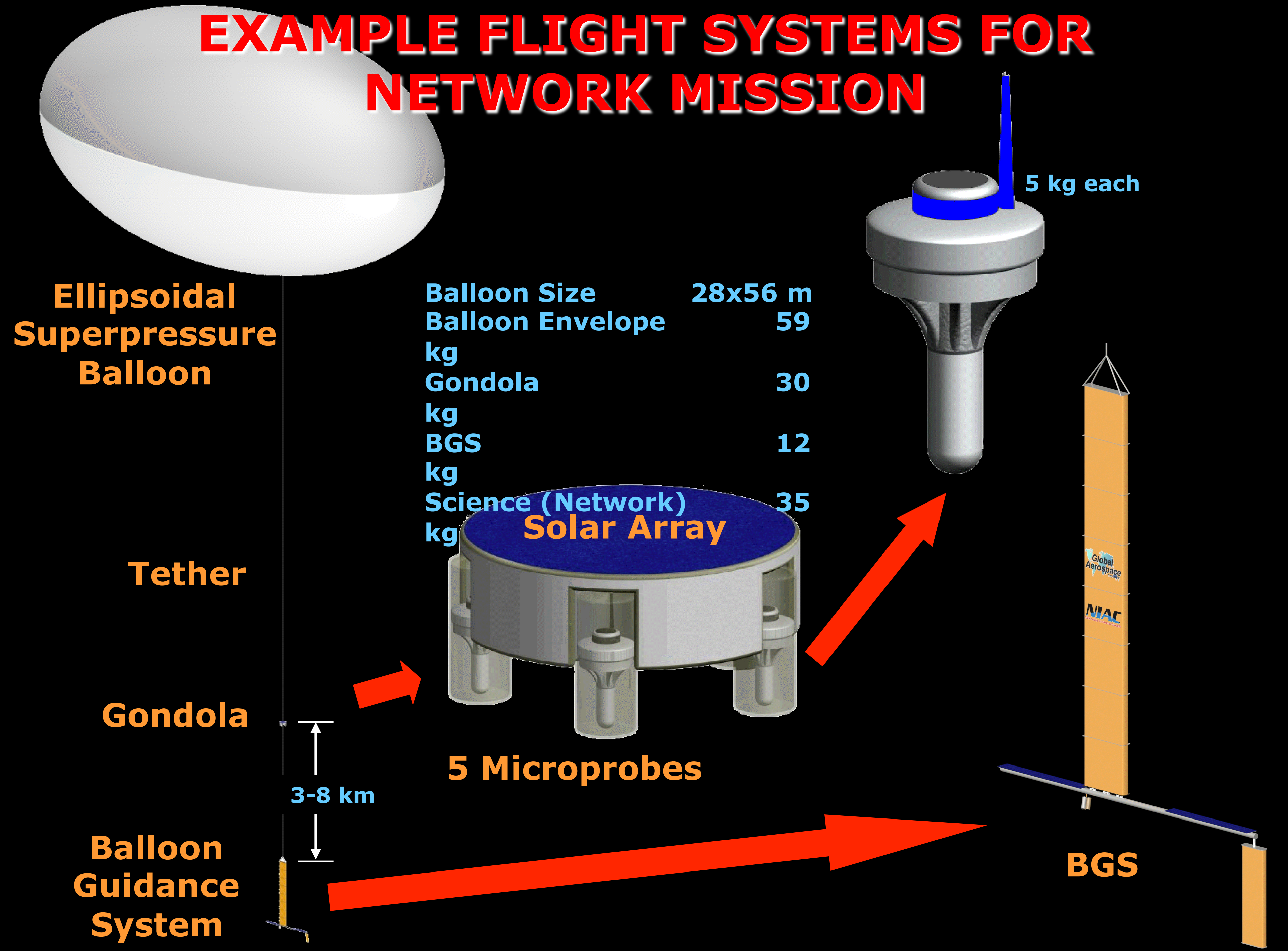
A NEW PLATFORM FOR EXPLORATION

- **Orbiters are not *in situ***
- **Landers do not move**
- **Rovers have very limited range**
- **Airplanes or gliders last for just a few hours**
- **Airship propulsion makes them heavy and difficult to deploy**
- **Free balloons are totally at the mercy of the winds**

Guided, long-duration balloon platforms have global reach



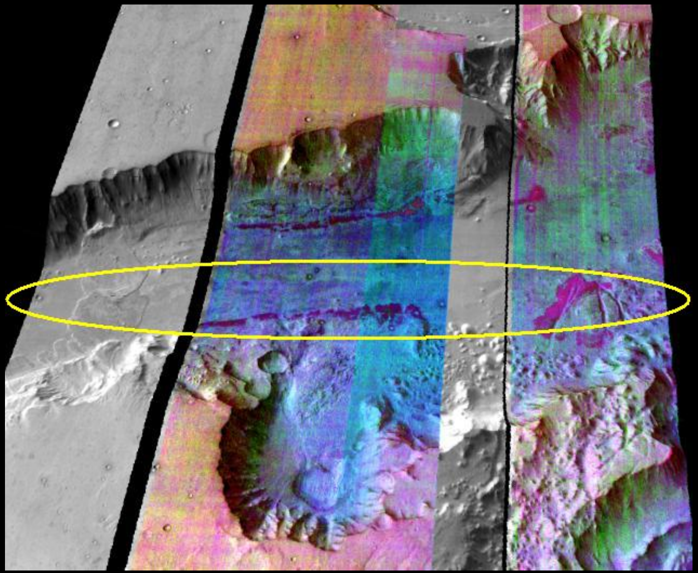
EXAMPLE FLIGHT SYSTEMS FOR NETWORK MISSION



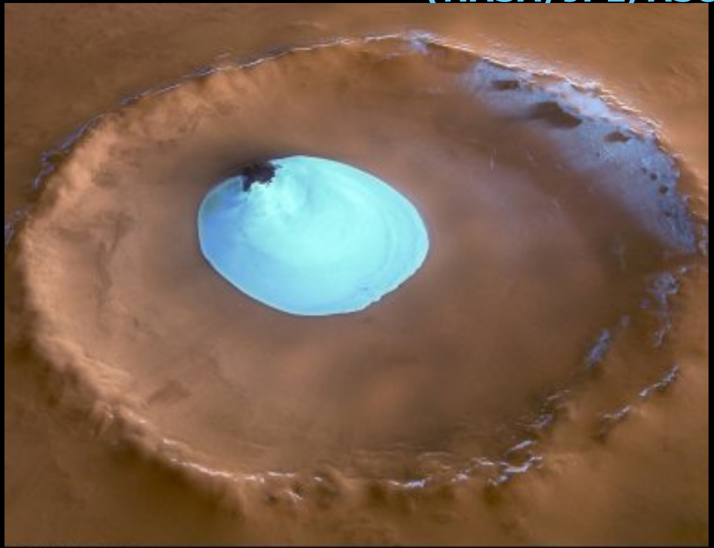
Balloon Size	28x56 m
Balloon Envelope	59 kg
Gondola	30 kg
BGS	12 kg
Science (Network)	35 kg

EXPLORATION CAPABILITIES

- Global planetary coverage
- Heavy, power-intensive payloads (90 kg and 200 W in 3 to 10 years, 170 kg and 400 W >10 years)
- Long flight duration: 700 days (1 Mars year)
- Autonomous navigation and guidance, target acquisition
- Targeted overflight of surface sites and precise delivery of science probes
- High-resolution imaging (1-10 cm visible & 0.1-10 m IR), elemental, magnetic and gravity observations and surveys
- In situ atmospheric chemistry and circulation
- Landing sites reconnaissance, navigation beacon emplacement



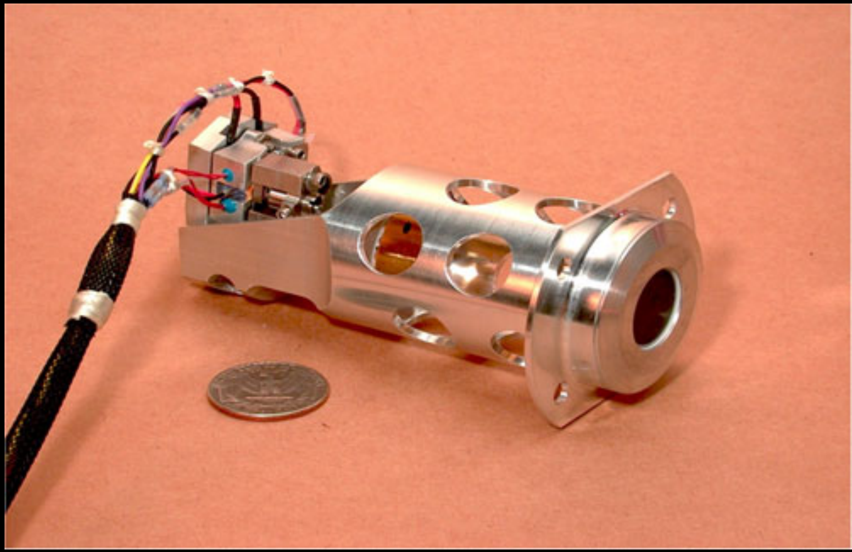
Olivine outcrop and DS-2 landing ellipse (NASA/JPL/ASU)



Water ice lake inside a crater on Mars (ESA)

SEARCH FOR ORIGIN OF ATMOSPHERIC METHANE

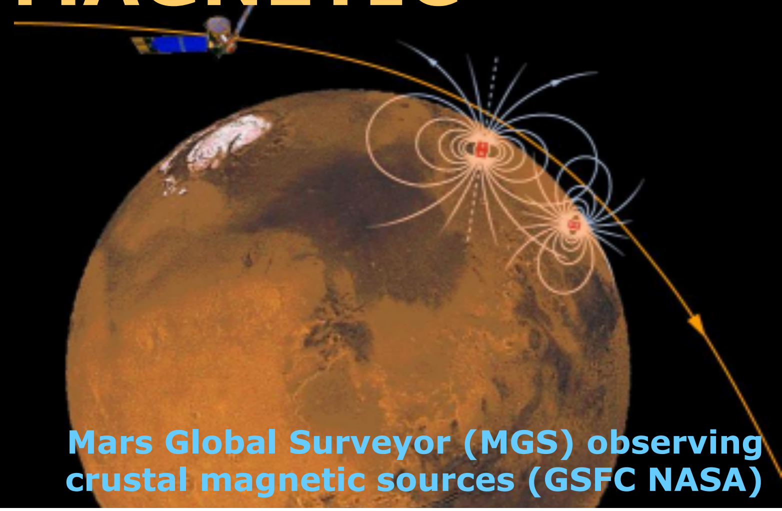
- **Methane-making organisms discriminate between isotopes as they feed on a global reservoir of CO_2**
- **Measure the C^{12}/C^{13} ratio in the methane.**
- **If it is different from the isotope ratio in the CO_2, it would offer strong evidence for a biological source.**
- **Guided balloons enable planetary-wide search for the sources of methane**



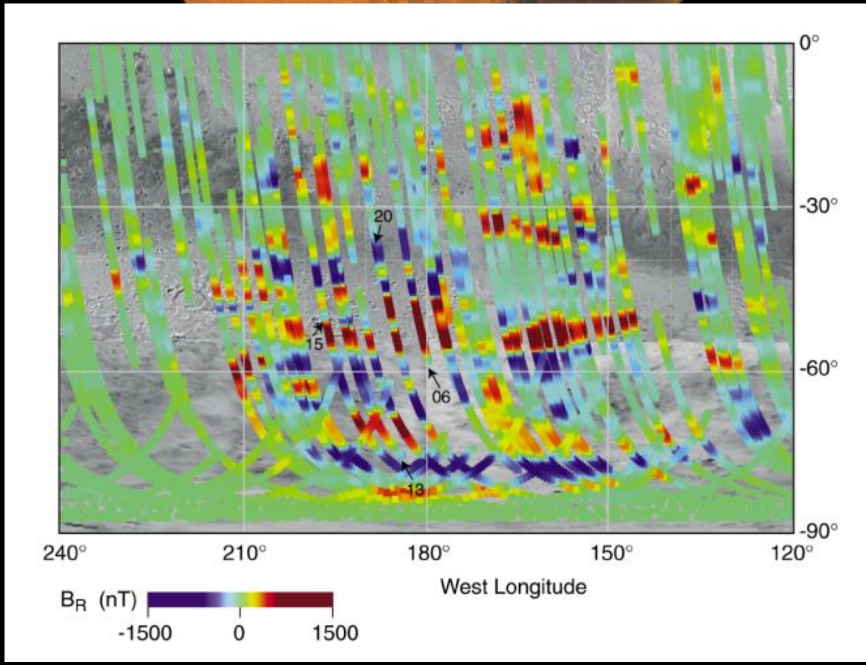
Tunable Laser Spectrometer for Atmospheric and Sub-surface gas measurements on Mars (NASA JPL)

CHARACTERIZE CRUSTAL MAGNETIC ANOMALIES

- MGS discovered strong crustal magnetic field anomalies
- However, orbital measurements
  - Lack required resolution to resolve origin of anomalies, and
  - The solar wind obscures weak fields
- Understanding these anomalies will
  - Provide clues on crust evolution
  - Advance understanding of Martian extinct dynamo
  - Possibly identify subsurface structures that harbor life
- Balloon platform with an array of magnetometers can
  - Enable high-resolution observation of crustal magnetic anomalies
  - Enable detection of weak anomalies via gradient measurements



Mars Global Surveyor (MGS) observing crustal magnetic sources (GSFC NASA)

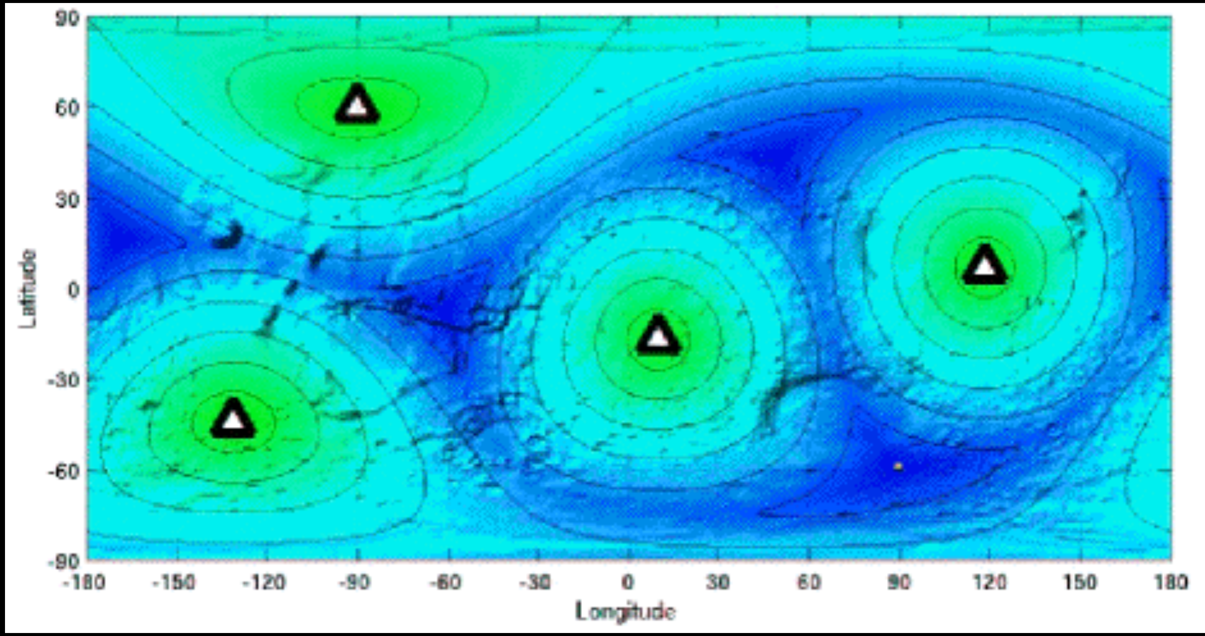


Map of crustal magnetic anomalies on Mars (GSFC NASA)

EMPLACEMENT OF SURFACE NETWORKS ON MARS

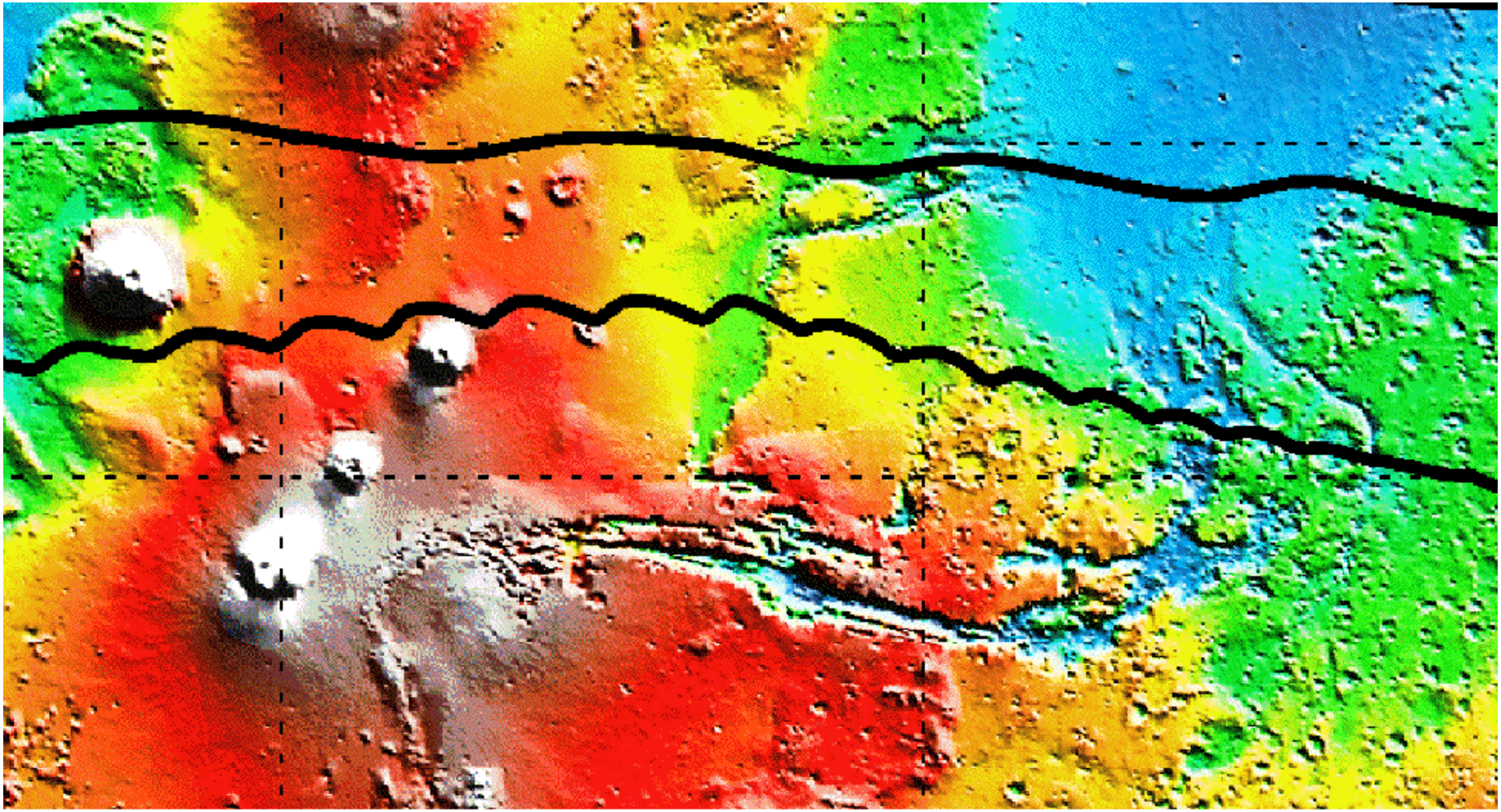
A single guided balloon platform can
- Carry tens of mini-labs
- Deploy meteorological & seismological networks

Tetrahedron Seismometer Network

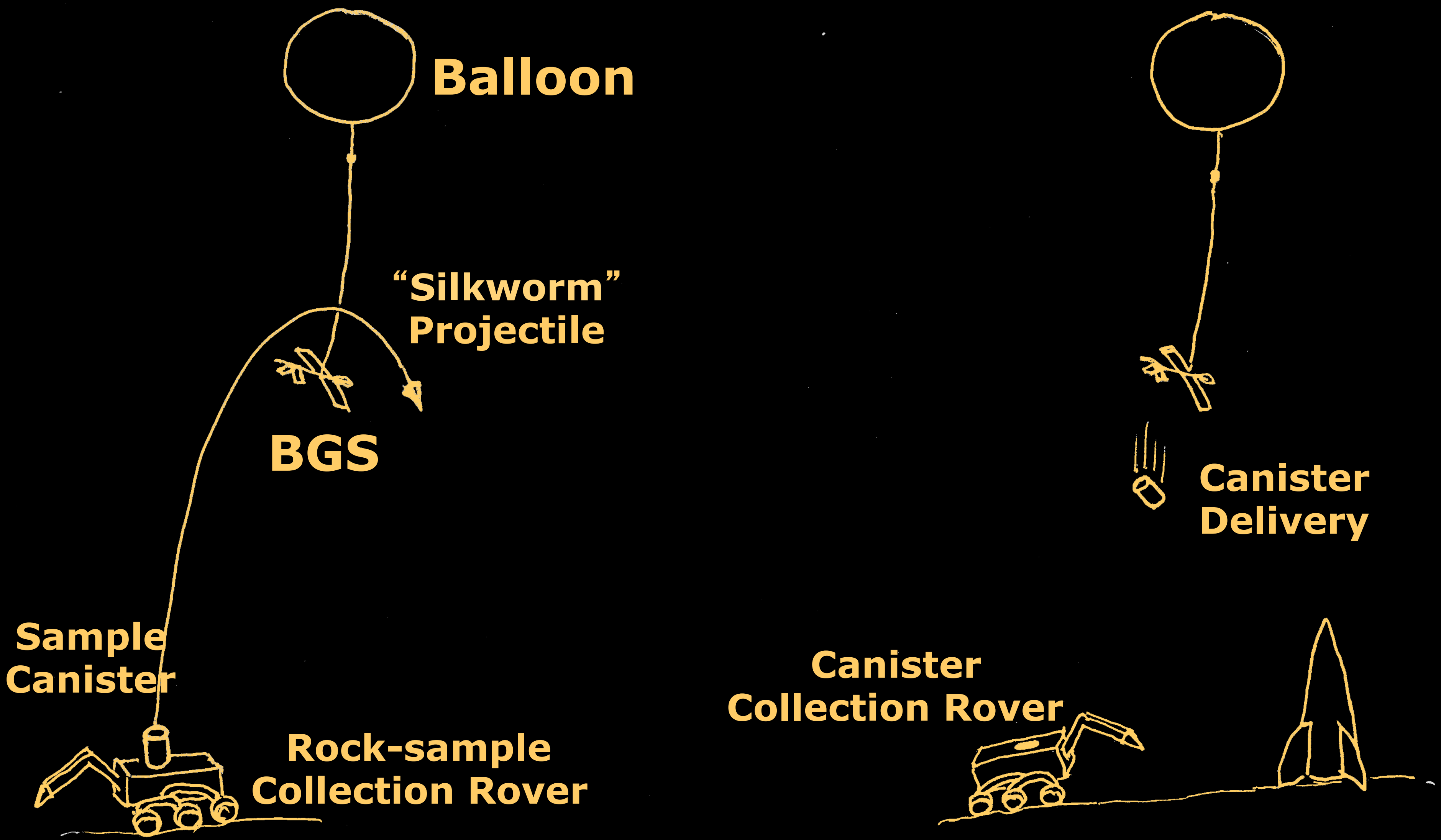


Mars Meteorological and Seismometer Probe

SAILING ACROSS THE MARTIAN EQUATOR



SAMPLE RETURN ASSIST



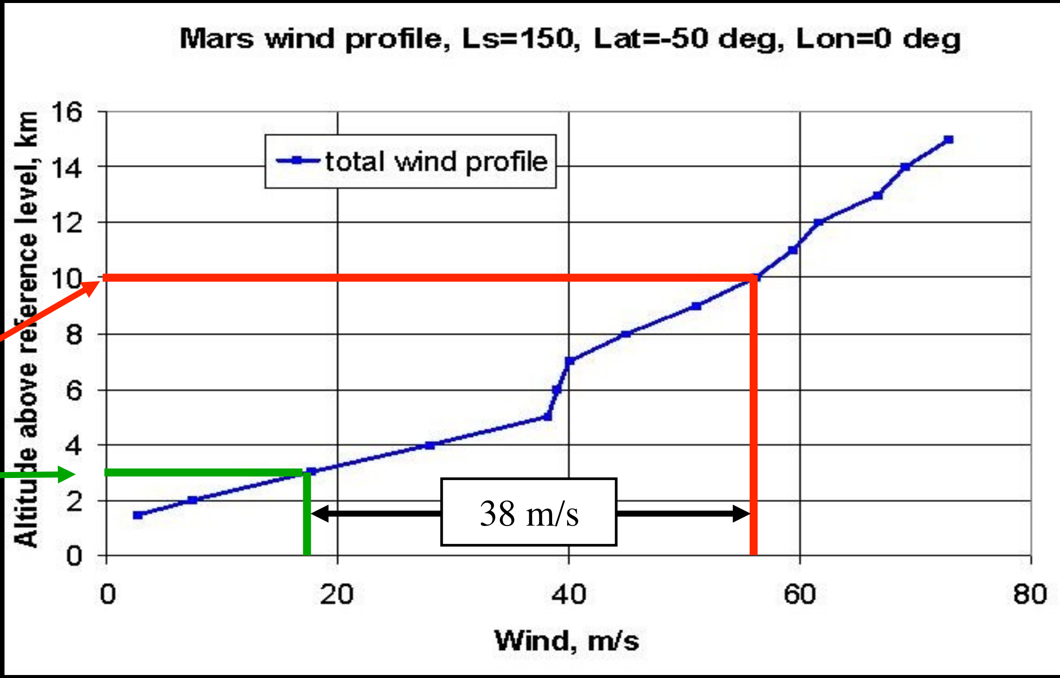
THE OTHER SIDE OF MARS **SAMPLE RETURN ASCENT VEHICLE**

SUMMARY

Guided Mars balloon platforms

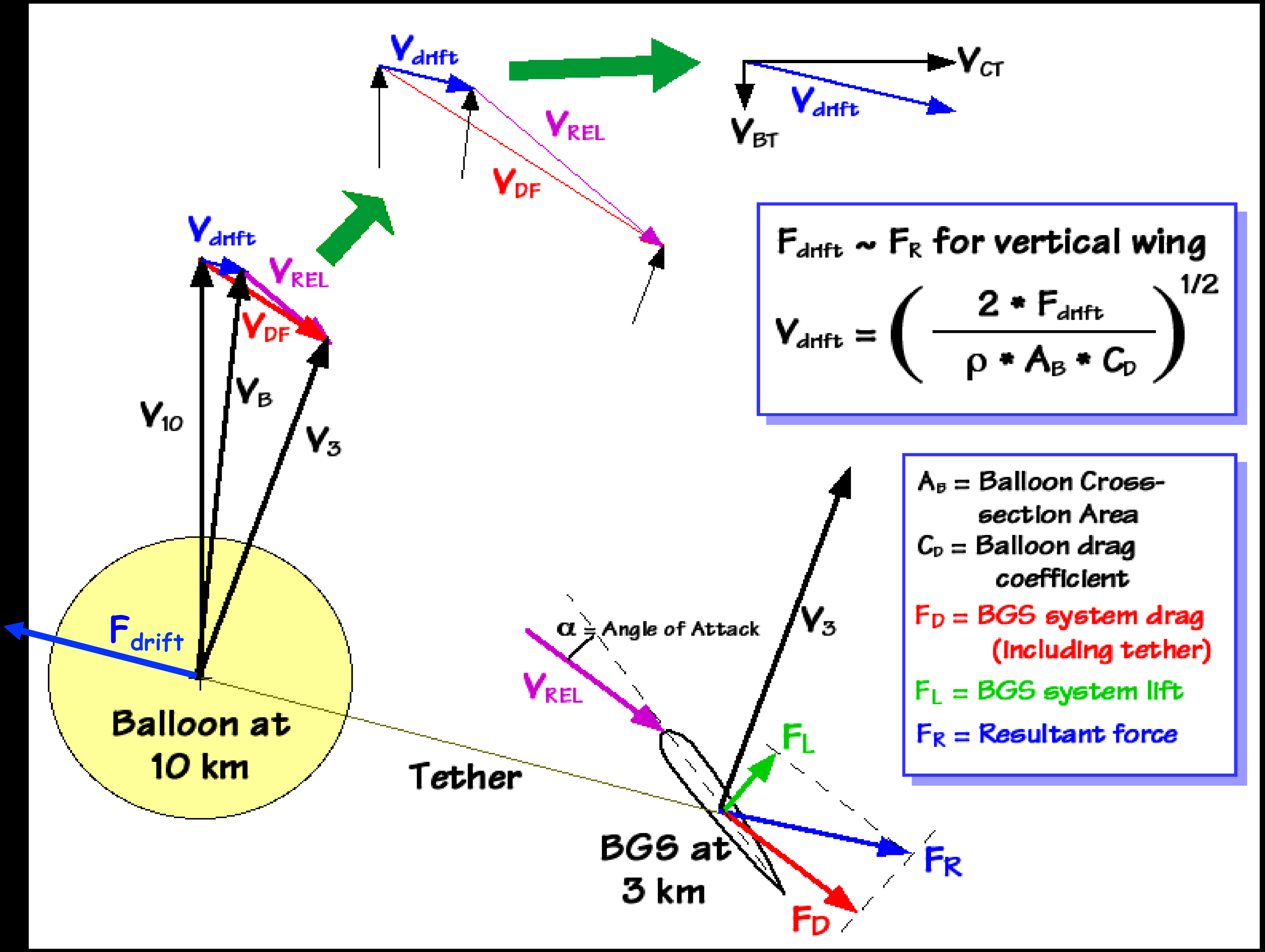
- Extend the reach of and work synergistically with orbiters, rovers, and landers
- Can be a relatively low-cost component of future Mars exploration
- Enable revolutionary new planetary exploration capabilities at Mars

MARS WIND PROFILE AND BGS

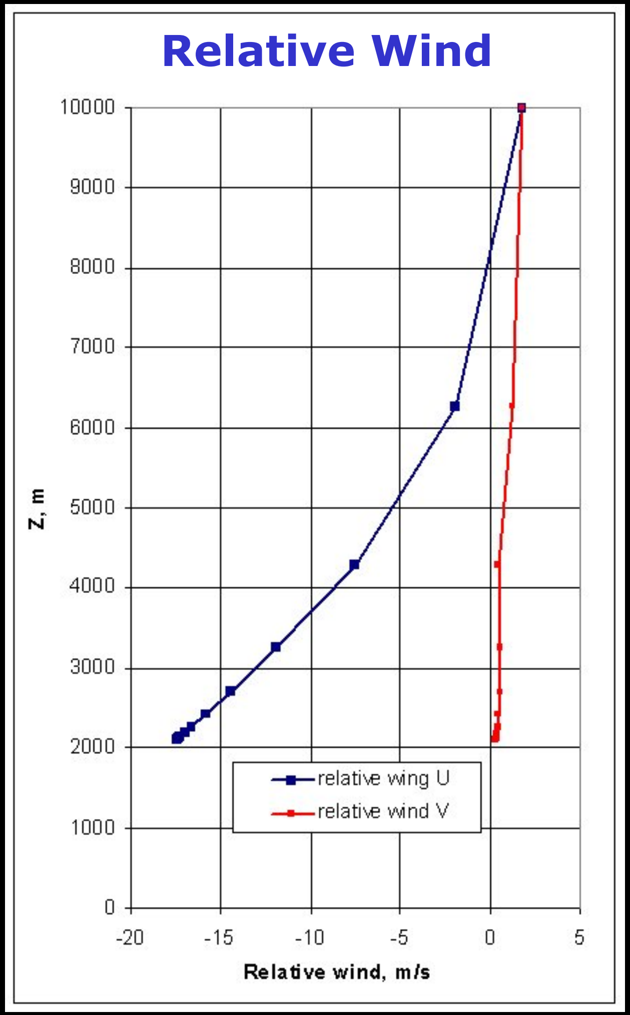


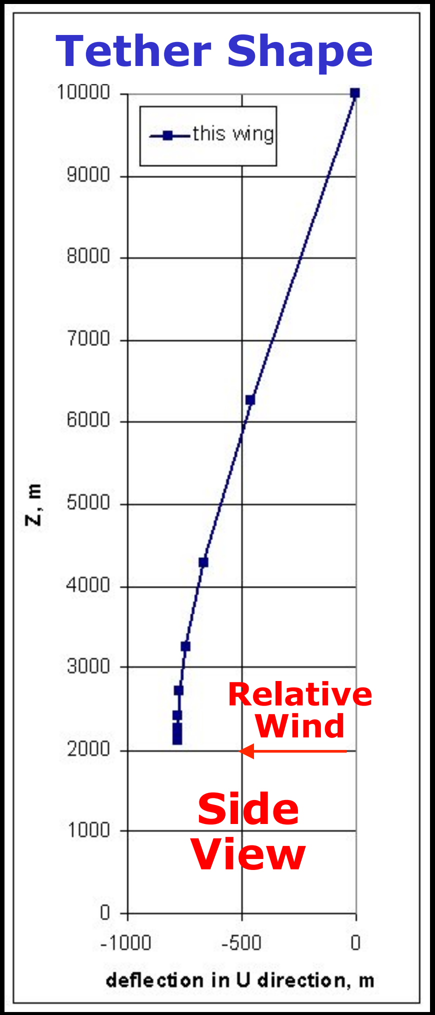
- Winds vary with altitude
  - Balloon at 10 km
    Density = 0.00645 kg/m³
  - Wing at 3 km
    Density = 0.01186 kg/m³
  - Relative wind velocity ~ 38 m/s
- Wing generates lift force
  - "Lift" force is horizontal
  - force is transmitted by tether to balloon
  - balloon drifts relative to local air mass
  - balloon drag ≈ wing lift
- Wing is in denser air than balloon
  - 3 km : 10 km (1.84x)
  - equivalent wing area increased relative to balloon

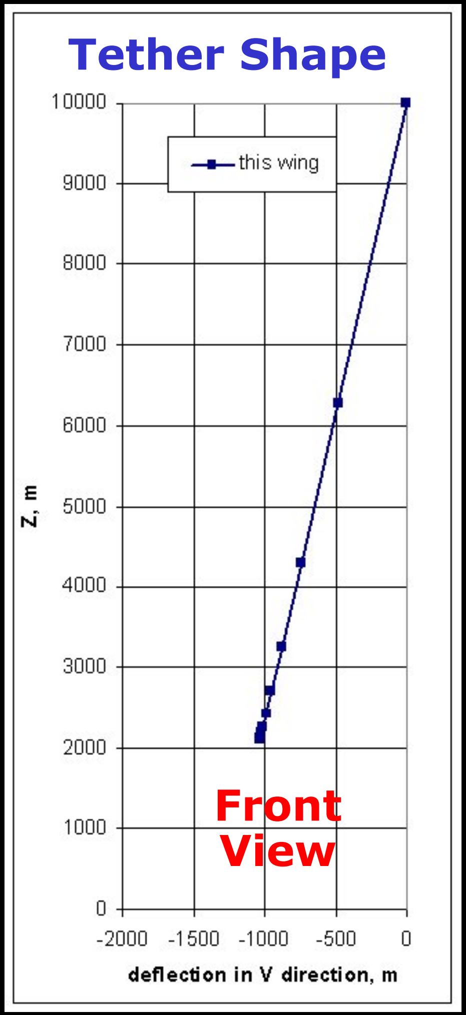
BGS OPERATION



BGS PERFORMANCE ANALYSIS: STRONG ZONAL FLOW

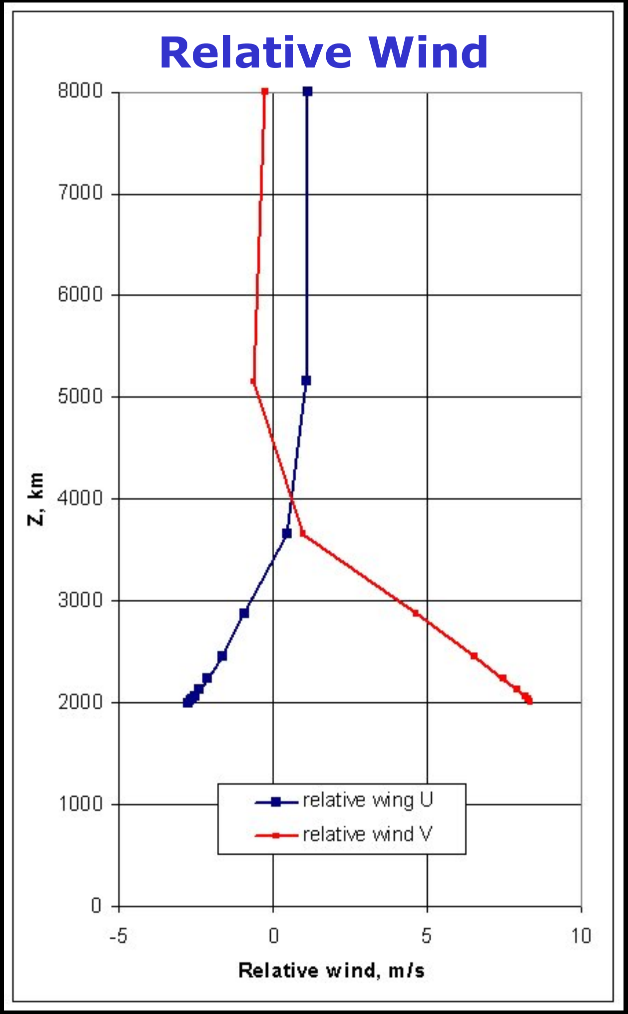


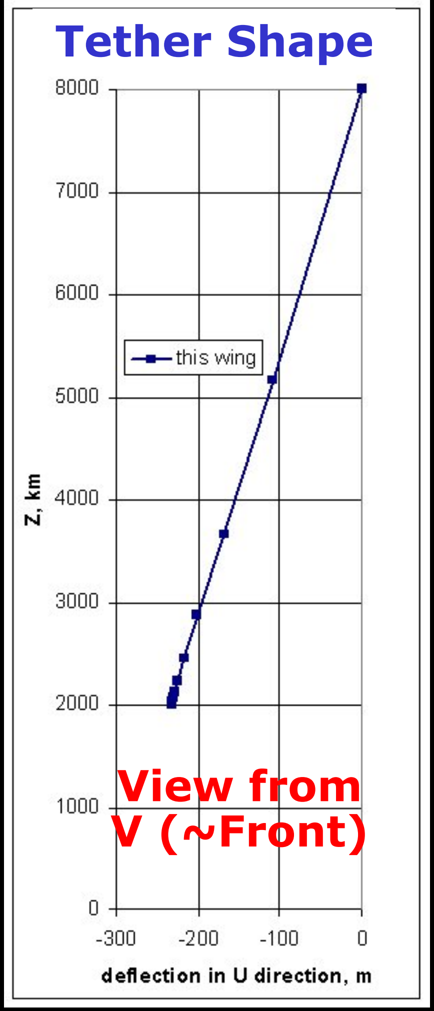


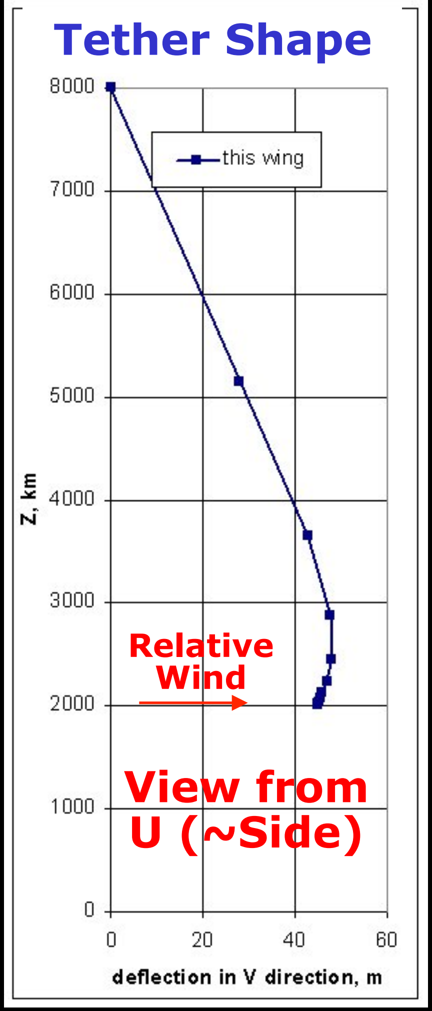


- **BGS V_{rel}=-18 m/s**
- **BGS ΔV =-1.8 m/s**

BGS PERFORMANCE ANALYSIS: WEAK FLOW

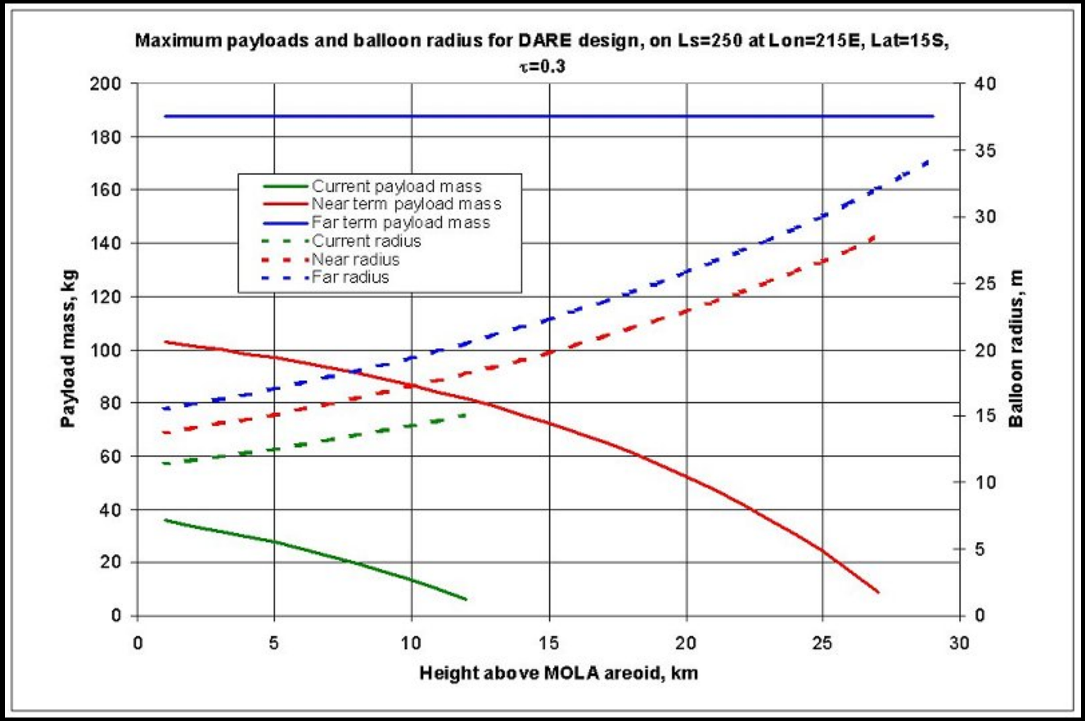


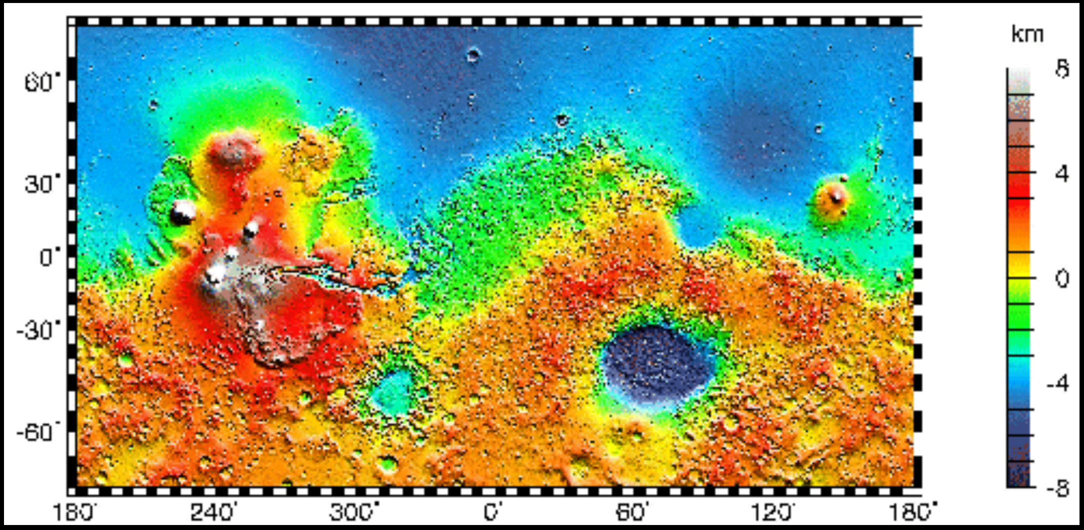




- BGS V_{rel}=9 m/s
- BGS ΔV =1 m/s

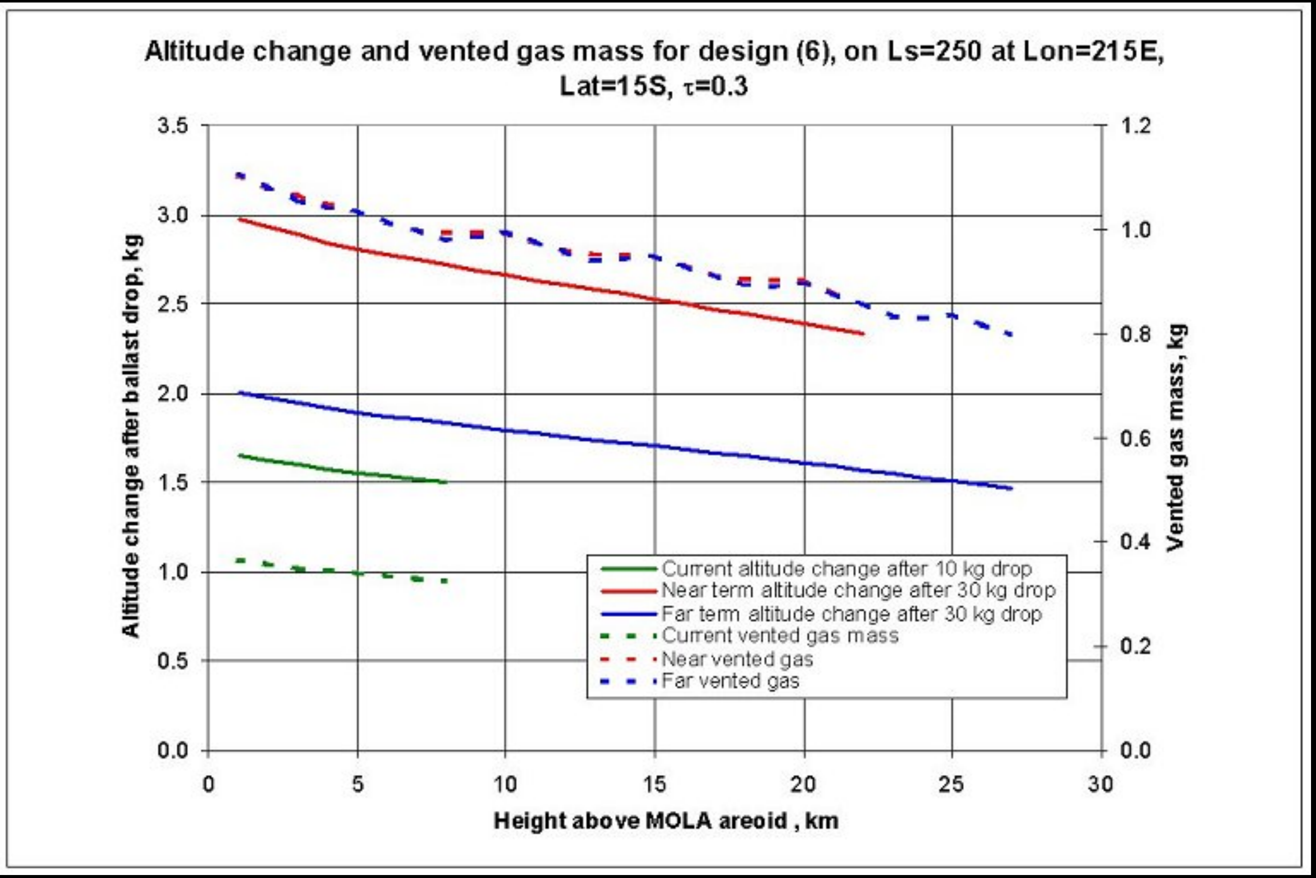
PAYLOAD VS. ALTITUDE





- **Height of atmospheric density levels lower by 4 km in dusty atmosphere**
- **Balloon to float 2-3 km above southern highlands in dust storm**
- **6 km at τ =3**
- **M=87 kg, R=17.2 m**
- **Altitude of 10 km at normal conditions**

ALTITUDE CHANGE AFTER PROBE RELEASE



- **Releasing 30 kg of probes raises altitude by 3 km**
- **Increase in super-pressure can be relieved by venting 1 kg of gas (out of 8 kg)**

KEY TECHNOLOGIES

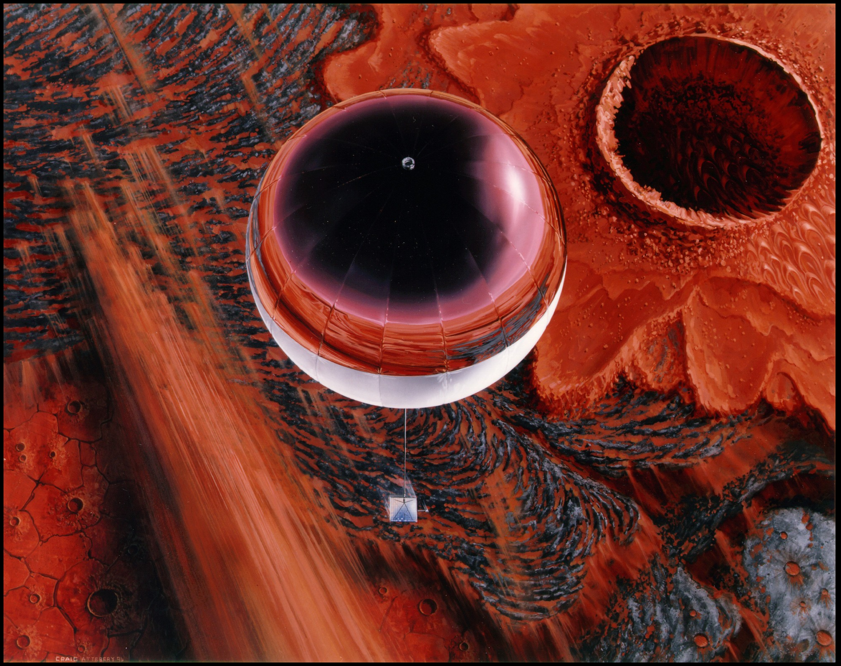
- Advanced Balloon Materials
- Balloon Guidance System (BGS)
- Entry, Descent and Inflation (EDI)
- Autonomous Navigation & Guidance in Mars winds
- Mars Balloon performance modeling

MARS BALLOON

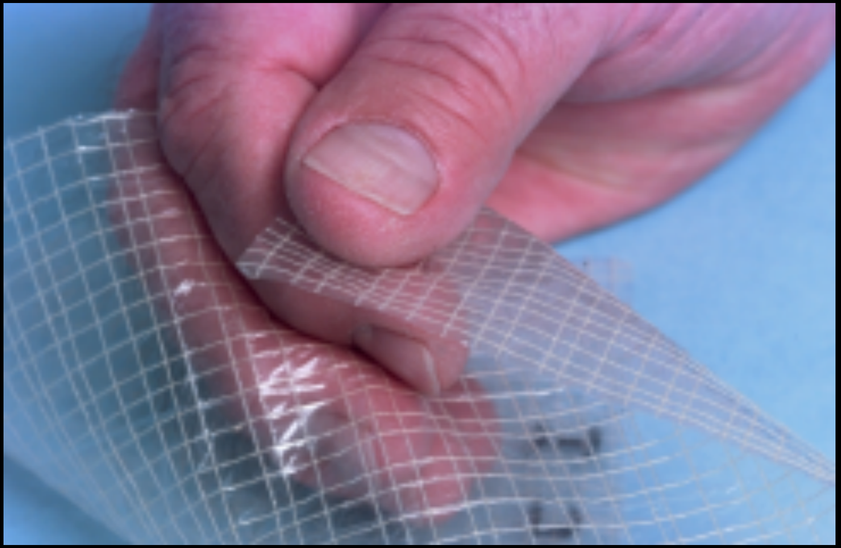
- **Low-mass high-strength envelope material**
  - **composite material**
  - **1-μm Mylar/38-Denier PBO thread/3- μm PE film**
  - **areal density of 0.012 kg/ m^2**
  - **Nano-tubes fabric in future?**

- **Superpressure sphere**

- **Aluminized top, white bottom to prevent CO_2 condensation**



Mars balloon concept

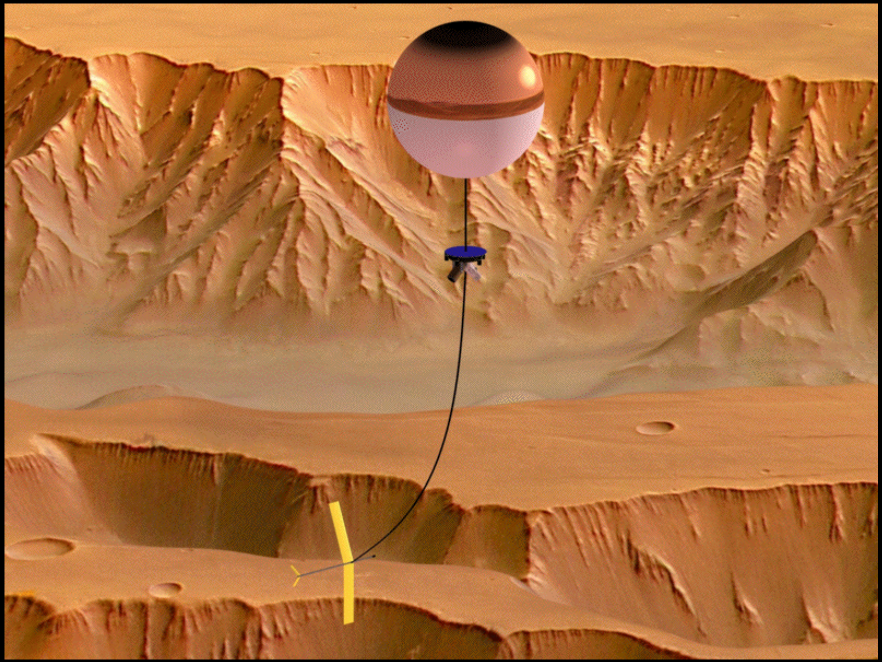


Composite Mars balloon material

EDI

- Mach 2 parachute at 13-28 km
- Careful balloon envelope deployment
- Cryogenic H_2 inflation - near-term technology
  - Inflation gas (8.3 kg H_2)
  - Combustion gases (0.14 kg H_2 and 1.14 kg O_2
  - Heat exchanger
- Float at 8 km after 20 min
- Make-up gas for >100 day missions
  - ~1.6 kg H_2 per year minimum
  - Collect and crack ambient H_2O for H_2 (10^{-4} kg H_2O per kg of atmosphere)

AUTONOMOUS NAVIGATION AND GUIDANCE



- Navigation
  - star camera
  - trajectory forecast
  - orbiter communication
  - surface feature recognition
  - control algorithms
- Target acquisition
  - onboard target database
  - surface feature recognition
  - targets of opportunity
  - camera attitude sensor and controller